Investigation

GAS LAWS IN ACTION - PROPANE

Background Information

Propane combines many of the storage and transportation advantages of a liquid with the fuel advantages of a gas. Under normal atmospheric pressure and temperature, propane is a gas. Under moderate pressure or lower temperatures, however, propane changes into a liquid. The liquid propane is vaporized as needed to fuel vehicles or other equipment.

Charles's Law

According to Charles's law, the volume of a fixed mass of gas at a constant pressure varies directly with absolute temperature. Propane illustrates this law. As the temperature of propane gas is lowered, the molecules move closer together and the volume of the gas decreases. At minus 44° F and atmospheric pressure, propane exists as a liquid. Kept under moderate pressure (e.g., 127 pounds per square inch at 70° F), propane can be transported, delivered and stored in a closed container as a liquid. When liquid propane is vaporized for use, the resulting gas has a volume 270 times that of the liquid.

Charles's gas law: $$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Where:

- **V_1 = original volume of a gas sample**
- **V_2 = new volume of a gas sample**
- **T_1 = original absolute temperature of a gas sample (kelvin*)**
- **T_2 = new absolute temperature of a gas sample (kelvin)**

* Absolute temperature is measured in degrees kelvin. A kelvin is the same as a degree Celsius. The two differ only in having different reference points. Zero degrees Celsius is defined as the freezing point of water, but zero degrees kelvin is absolute zero. Water freezes at 273.15 kelvins and boils at 373.15 kelvins. Any temperature can be converted from Celsius to kelvins by adding 273.15.

NAME: CLASS PERIOD: DATE:

GAS LAWS IN ACTION INVESTIGATION CONT.

Boyle's Law

Boyle's law of gases complements Charles's law. Boyle's law states that when the temperature is held constant, the volume of a fixed mass of gas in a container varies inversely with pressure. In other words, as long as the temperature doesn't change, the higher the pressure, the lower the volume of the gas, and vice versa.

Boyle's gas law: $P_1 \times V_1 = P_2 \times V_2$

Where:

P_1 = original pressure of a gas sample
V_1 = original volume of a gas sample
P_2 = new pressure of a gas sample
V_2 = new volume of a gas sample

Boyle's law explains why pressure-relief valves on propane tanks work. When the relief valve is opened, pressure inside the tank is released (lowered), as gas expands in volume and escapes through the relief valve. When the tank or cylinder is re-pressurized by closing the valve, the boiling stops and the gas and liquid inside the tank return to a state of equilibrium.

Gas Laws Work Together

Outside temperature is continually changing. The air surrounding a propane tank or cylinder transfers heat to the propane inside. When this happens, the volume of liquid and the pressure inside the tank increase. The pressure can change as much as 50 psi on a single day. To compensate, propane tanks are filled to about 80 percent of their capacity. This allows room for the propane to expand safely.

Part I: Chill It

Materials

round helium-quality balloons
thermometer
string
marker
water
helium canister
rubber band
metric ruler
wash tub
ice

NAME: CLASS PERIOD: DATE:

GAS LAWS IN ACTION - PROPANE INVESTIGATION CONT.

Procedure

1. Fill a balloon with helium to near capacity. Hold the end; do not tie off.
2. Have one partner hold balloon while the other partner inserts a thermometer into the balloon.
3. Make sure temperature readings will be visible. Then tightly secure the thermometer inside the balloon with a rubber band.
4. Measure the circumference of the balloon. Wrap the string around the balloon at its widest point. Mark the string with the marker and measure the distance with the metric ruler.
5. Record the circumference of the balloon on the data table.
6. Measure and record the temperature of the gas particles inside the balloon.
7. Cool the gas particles inside the balloon by placing the balloon upside down (themometer up) in a large wash tub of ice and water for three to five minutes.
8. Measure and record the temperature of the gas particles inside the balloon.
9. Take another measurement of the circumference. Be careful, because shrinking of the balloon will cause wrinkling of the surfaces.
10. Record the circumference of the balloon on the data table.
11. Share your data with other students.

Observations

Circumference of balloon (cm)	Temperature (C^O)	Radius	Volume cm^3

1. Assuming that the balloon is a sphere and using the information below, calculate the radius of each balloon _____

   Diameter = circumference /3.14
   Radius = 1/2 diameter

2. Again assuming the balloon is a sphere and using the information below, calculate the volume of the balloon _____

   Volume = 4.0 x 3.14 (radius x radius x radius) / 3.0

NAME: CLASS PERIOD: DATE:

GAS LAWS IN ACTION - PROPANE INVESTIGATION CONT.

3. Calculate the volume of the balloon after it was plunged into the ice bath.

_____

Graph the relationship between volume and temperature for all balloons.

Part II: The Big Squeeze

Procedure

1. Move the desks in the classroom to form a large square with open space in the middle.
2. Pick four to eight students to represent gas molecules.
3. Using the formula below, calculate the volume of the space. Use the height of the tallest student as the height of the cube.

   volume of a cube = length x width x height

4. Record the volume of the space on the data table.
5. The students that represent the gas molecules should move to the middle of the square, blindfolded and with arms across their chests.

GAS LAWS IN ACTION - PROPANE INVESTIGATION CONT.

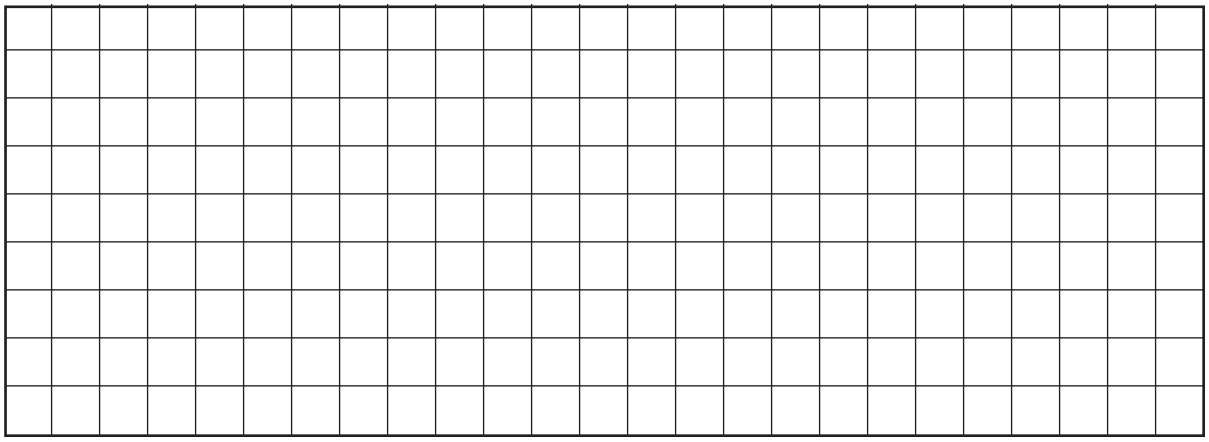
6. One student should be given the task of timekeeper. This student should keep time by clapping or beating out a rhythm that dictates the speed of the gas molecules. This student should watch a clock and use a time interval of four seconds for each clap.
7. The remaining students should sit at the desks and record the number of collisions that occur in one minute between gas molecules and between gas molecules and the edges of the container (desks).
8. When the timekeeper is ready, the gas molecules are to walk with the beat of the timekeeper, using small steps, until they collide with another gas molecule or the edges of the container. Once a collision occurs, students are to back away from the collision again, slowly, still keeping pace with the timekeeper until they collide again.
9. If desks are moved slightly when collisions occur, the recorders are to quickly move the desks back into place.
10. Recorders post their results on the board.
11. Repeat the experiment 3 times.
12. Move the desks in to create a smaller space.
13. Predict the number of collisions that will occur within the smaller space.
14. Repeat steps 2-10.
15. Calculate the average number of collisions for each trial.
16. Record the class averages as pressure on the data table.

Trial	Volume (cm^3)	Pressure
1		
2		
3		
1		
2		
3		

NAME: CLASS PERIOD: DATE:

GAS LAWS IN ACTION - PROPANE INVESTIGATION CONT.

Graph the relationship between volume and pressure.



Conclusion

1. Describe the relationship between temperature and volume of a gas. _____

_____

2. Demonstrate, by using the formula for Charles's law, that the data collected support this gas law. _____

3. Describe the relationship between volume and pressure. _____

_____

4. What phase did the molecules represent when the desks were in the first position?

_____

GAS LAWS IN ACTION - PROPANE INVESTIGATION CONT.

5. Explain what was being demonstrated in terms of pressure, volume, and phase when the desks were moved closer together. _____

_____

6. Demonstrate, by using the formula for Boyle's law, that the data collected supports this law.

_____

Application

7. When a propane tank warms during the heat of the day, what happens to the volume?

_____ Why? _____

8. At atmospheric pressure, propane gas can be liquefied by cooling it to _____.

   Below this temperature, the gas will not vaporize.

9. Propane can be cooled to this temperature by first _____ the gas, and then allowing it to expand rapidly, which cools the gas.

10. When a can of pressurized liquid, such as hair spray, is shaken the liquid inside can be heard sloshing around. Then, when the nozzle is pushed down the _____ in the can decreases.

11. How do the results from pushing the nozzle on a hair spray can relate to propane stored in a tank? _____

_____

Going Further

12. Work together in a group to design another chemistry theater that would demonstrate Charles's law.